Designing flexible and stretchable circuits and displays

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ABSTRACT

All technologies on flexible and stretchable foils suffer from intrinsic parameter variation. Designing for these technologies must start from a detailed analysis of these variations. Mapping these variations on the different design topologies that can be used to design flexible circuits, enables to predict and optimize the soft yield of these circuits. This methodology has been applied to designs of organic and oxide RFID and NFC tags, microprocessors on foil and also integrated linedrivers for displays.

1. DESIGNING FOR TECHNOLOGIES ON FOIL

Display backplane technology has always been a technology at a much lower cost per area that classical silicon technologies. Moreover, these technologies can also be ported to technologies on foil, by laminating the foil on the glass carrier prior to the process flow. After processing, the foil can be delaminated from the glass plate and circuits can be cut out the foil. As a consequence, when no top performance is needed, this is an ideal method to obtain huge quantities of small circuits at low cost.

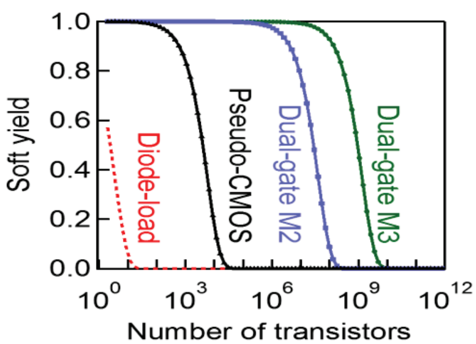

Fig. 1 Assessment of the soft-yield as a function of the number of transistors for some design topology. It imposes the limits of the design complexity.

However, once a technology is ported to foil, new challenges appear, such as amongst others: (1) non-uniformities due to line-edge roughness and dielectric roughness (2) semiconductor material non-uniformity (3) unipolar transport, ... Designing for technologies on foil hence requires a detailed study of these parameter variations [1], prior to the onset of the design. From this study, the maximum level of complexity (i.e. maximum number of transistors) can be defined (see Fig. 1), assuming a soft yield close to 100% is expected.

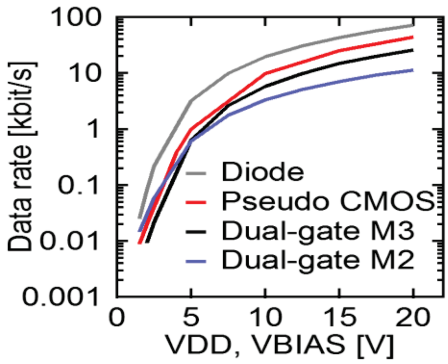

Fig. 2 Obtained data rate for the dies shown in Fig.3

2. ORGANIC AND OXIDE RFID AND NFC TAGS

One of the first products to be envisaged, when large amount of small circuits can be produced at low cost, are RFID and NFC tags, as these circuits will enable the Internet of Things (IoT). Rectification at 13.56 MHz has acted as an enabler [2] and soon after, the first demonstrators of organic RFID tags appeared [3,4]. The performance of these RFID and NFC tags has gradually increased [5], by improving the technology and by changing the semiconductor (e.g. towards a-IGZO on foil [6]). At present, the technology is capable to realize tags that are driven by a commercial USB-connected NFC-reader [6]. From power voltages below 2V, the circuits start to operate, but at a rather low data rate (see Fig. 2). Fig. 3 shows the die pictures of the NFC tags in different topologies. Fig. 4 compares the reading distance that can be obtained and Fig. 5 shows the signal that is produced by the code generator inside the tag.

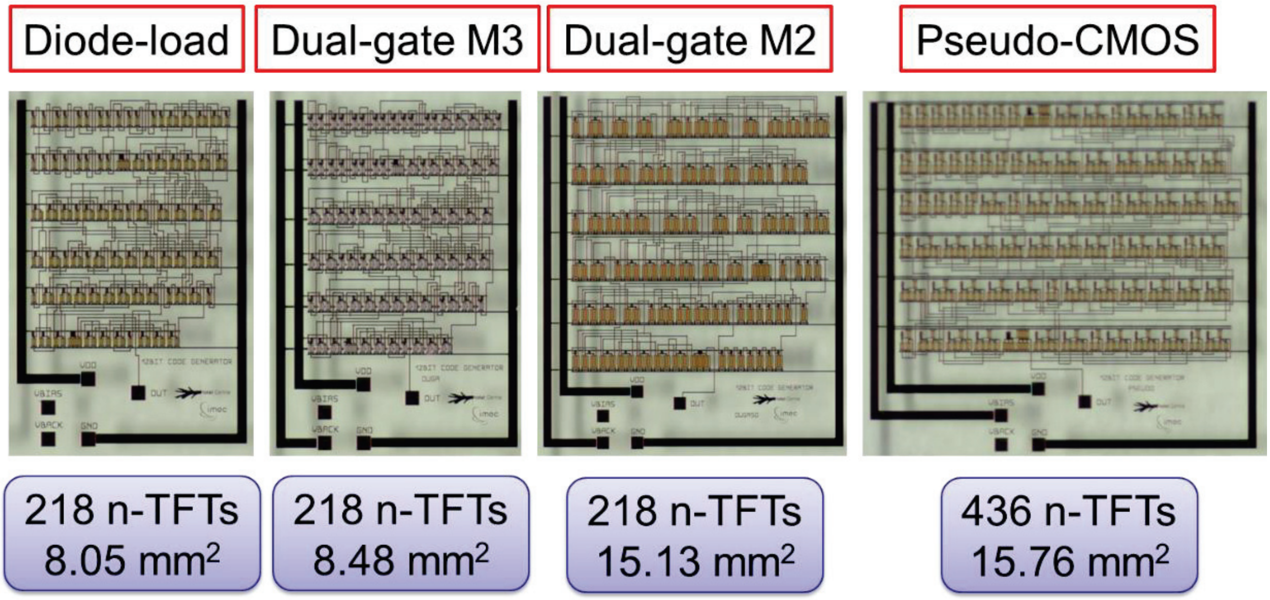

Fig. 3 Die pictures of 4 topologies in which flexible NFC tags are implemented.

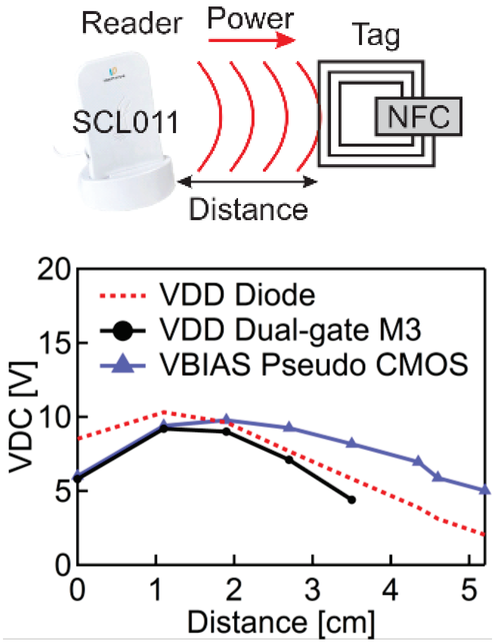

Fig. 4 Obtained NFC tag power voltage as a function of the distance from the NFC reader.

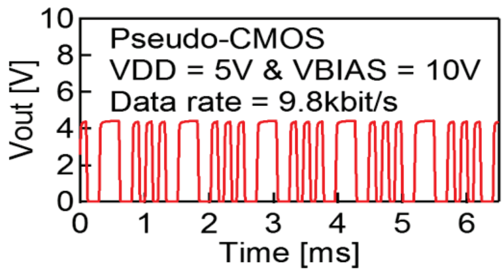

Fig. 5 Typical signal obtained from a 12 bit code generator on flex in the Pseudo CMOS technology.

3. APPLICATION TO INTEGRATED LINEDRIVERS ON FLEXIBLE FOILS.

For the development of rollable displays with a reasonable small bezel, integrated linedrivers are of paramount importance, as no silicon chips can be laminated along the rolling axis on foil and the complete routing of all select lines to the rigid edge of a rollable display would require a bezel which is too wide. We have compared 11 different logic topologies for the implementation of these linedrivers in both ECL and Self-Aligned a-IGZO technologies on foil and we have verified their performance. It emerged that a combination of static pseudo-CMOS [7] with bootstrapped select line driver [8] outperforms the other topologies in terms of speed and soft-yield.

4. TOWARDS TRULY STRETCHABLE DISPLAYS

As the challenges for flexible circuits and rollable displays are getting understood, it is time to outreach towards stretchable displays and circuits. To ensure stretchability, new features (such as a.o. meanders) need to be incorporated into the design. First demonstrators are promising, indicating the road to go further.

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